



Enhancing Learners' Engagement and Conceptual Mastery in Geometry through Innovative Teaching Resources in the Era of the Fifth Industrial Revolution in Okrika, Rivers State

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Abstract

This study investigated the impact of teaching resources on learners' engagement and conceptual mastery in Geometry, utilizing a non-randomized, non-equivalent quasi-experimental design. The population consisted of all 1,365 Senior Secondary Two (SS2) students from six public schools in Okrika Local Government Area. A sample of 150 (SS2) students was drawn from three of the six randomly selected schools. Three intact classes from CSS Kalio-Ama, CSS Ogan Ama, and CSS Okochiri participated, undergoing pretests before treatment and post-tests afterward to evaluate instructional effectiveness. The study employed the Geometry Performance Test (GPT), an instrument validated by experts in Mathematics Education and Educational Psychology to ensure face and content validity. Reliability was established through the test-retest method with 15 students from a non-sampled school, achieving Pearson correlation coefficients of 0.72 and 0.83, indicating high reliability. Results showed that manipulatives significantly enhanced conceptual mastery and understanding, as evidenced by improved post-test scores and consistent learners' engagement. Visual aids increased score consistency but did not significantly affect conceptual mastery. Digital tools showed slight improvements but mixed outcomes, suggesting some students faced challenges. Hypothesis testing confirmed that the type of instructional material significantly influences performance (H_{01} rejected), while gender had no significant impact (H_{02} accepted). Recommendations include a blended instructional approach incorporating manipulatives, visual aids, and digital tools to accommodate diverse learning needs.

Keywords: Teaching Resources, Learner's engagement, Mathematics Education, Gender.

Introduction

The use of teaching resources in Mathematics education, particularly in geometry, has become increasingly relevant in discussions on effective teaching methodologies. Geometry, as a foundational subject in Mathematics, is essential for developing spatial awareness, logical reasoning, and problem-solving skills. Yet, students often face difficulties understanding geometric concepts due to their abstract nature. To address these challenges, educators have



advocated for the integration of teaching resources like manipulatives, visual aids, and digital tools that provide tangible experiences to support learning and concept mastery.

Research indicates that teaching resources significantly impact students' academic performance and conceptual mastery rates. Visual aids, such as charts and diagrams, help students to visualize geometric relationships, while physical manipulatives, like geometric solids, offer hands-on experiences that foster deeper understanding. Studies by Lukman (2022) highlight that teaching resources bridge the gap between theoretical concepts and practical understanding, facilitating more effective learning outcomes in mathematics classrooms. Additionally, interactive digital resources are noted to engage students actively and adapt to diverse learning styles, enhancing both engagement and conceptual mastery in subjects like geometry Niyibizi, et al., (2024).

In recent years, educational research has focused on the correlation between instructional material utilization and improved learning outcomes. Studies have shown that when teaching resources are strategically integrated, they can lead to enhanced comprehension, longer conceptual mastery, and higher performance on assessments. Furthermore, educational frameworks emphasize the need for diverse and inclusive learning resources to meet the needs of all students, including those who may require additional support to grasp complex mathematical concepts. This article explores the types of teaching resources effective in teaching geometry, their impact on student outcomes, and insights from contemporary research on best practices in implementing these resources in geometry education.

Research has shown that teaching resources play a critical role in enhancing students' understanding and conceptual mastery in geometry, with potential variations in impact based on gender. According to Duru and Osakwe (2020), using manipulatives and visual aids in geometry can significantly enhance spatial reasoning skills, which may be particularly beneficial for female students who tend to report higher math anxiety. Their findings indicate that access to varied teaching resources can help close the performance gap by supporting confidence and comprehension in both genders. Similarly, studies by Onye and Dike (2021) demonstrate that female students particularly benefit from interactive digital resources in geometry, which offer hands-on, visually engaging experiences that enhance both conceptual mastery and understanding across gender lines.



Studies have also highlighted differences in conceptual mastery rates across gender when teaching resources are effectively integrated into the geometry curriculum. According to Afolabi and Olajide (2018), while both male and female students benefit from visual aids, female students tend to retain information better when lessons are supported by concrete manipulatives. This aligns with findings by Smith and Leonard (2022), who report that teaching resources such as models and diagrams encourage sustained engagement in female students, thereby improving conceptual mastery. These findings support the need for a gender-sensitive approach in selecting teaching resources, as conceptual mastery in geometry can be enhanced by tailoring resources that resonate with different learning styles.

Adalikwu (2013) found that the availability and use of instructional aids significantly enhance students' academic performance in senior secondary schools. This research work investigated the influence of teaching resources (teaching aids) on students' academic performance in senior secondary school Chemistry in Cross River State. The study revealed that students taught with teaching resources performed significantly better than those taught without teaching resources, and also that the use of teaching resources generally improved students' understanding of concepts and led to high academic achievements.

Duru & Osakwe (2020) conducted a quasi-experimental study examining the effects of teaching resources on students' geometry performance in Nigerian secondary schools. The study utilized manipulatives and visual aids, finding that students taught with concrete teaching resources demonstrated improved comprehension and conceptual mastery in geometry compared to those in traditional, lecture-based classrooms. Pre- and post-test results showed significant improvement in conceptual understanding and conceptual mastery among students exposed to these materials. The researchers recommend incorporating diverse instructional aids to address various learning preferences and enhance spatial understanding of geometric concepts.

Tarekegn & Tesfaye (2019) investigated the role of teaching resources in promoting conceptual mastery and understanding in geometry for Ethiopian high school students. Using a sample of 200 students, they applied a mixed-methods approach to assess the effectiveness of visual aids and digital simulations. Results indicated that digital tools, when combined with hands-on activities, significantly enhanced students' conceptual mastery. However, while digital materials promoted engagement, some students reported challenges with tool navigation. The



study recommends balanced use of technology and physical materials to optimize learning experiences in geometry.

Afolabi & Olajide (2018) In their study evaluated how different teaching resources affected geometry learning among Nigerian secondary students. They utilized manipulatives like geometric solids and visual aids, and observed that students who had access to these aids scored significantly higher on conceptual mastery tests. Their findings align with constructivist learning theories, suggesting that active engagement with materials helps students retain spatial and conceptual aspects of geometry. They advocate for teachers to prioritize hands-on learning methods over solely lecture-based approaches to maximize student engagement and performance.

Onye & Dike (2021) conducted a study on senior secondary school students in Nigeria, comparing groups exposed to traditional teaching versus those using enhanced teaching resources such as diagrams and physical models in geometry. The study found that students using these instructional aids showed improved problem-solving skills and conceptual mastery in geometric concepts. The intervention group's post-test scores were consistently higher than the control group's, confirming that tactile and visual engagement with geometry materials aids long-term memory conceptual mastery and understanding. Recommendations included adopting a structured curriculum that integrates visual aids.

Smith & Leonard (2022). This study focused on the use of interactive digital resources, such as geometry software and virtual manipulatives, to teach high school geometry. Smith and Leonard found that students learning with these digital tools performed better in conceptual mastery tests compared to their peers in traditional classrooms. Interviews revealed that students appreciated the ability to manipulate shapes virtually, which helped reinforce spatial reasoning. The study, however, notes that while digital tools improve engagement, they should be complemented with physical manipulatives to address diverse learning styles. The authors suggest that future curricula should blend digital and physical materials.

Statement of the Problem:

Despite geometry's critical role in developing spatial reasoning and problem-solving skills, Nigerian learners' engagement in this subject remains below expectations. The 2023 WAEC examiners' report highlights ongoing challenges, including inadequate understanding of core geometry concepts and low conceptual mastery rates among students, resulting in consistently



poor scores in national assessments. This performance issue may be due, in part, to the limited use of effective teaching resources in geometry teaching, as many educators continue to rely solely on traditional methods. Research by Duru and Osakwe (2020) emphasizes the positive impact of teaching resources, such as manipulatives and digital resources, on student engagement and understanding in mathematics, pointing to a need for broader adoption in geometry teaching. Similarly, Afolabi and Olajide (2018) find that appropriate instructional aids can significantly improve students' comprehension and conceptual mastery in complex subjects like geometry. Addressing these gaps by integrating diverse teaching resources to enhance geometry outcomes and foster long-term conceptual mastery.

Aim and Objectives of the Study

To investigate the effectiveness of various teaching resources in enhancing learners' engagement in mathematics in secondary schools. Specifically, the study is guided by the following objectives:



1. determine the mean difference among students taught using manipulatives, those taught using visual aids, and those taught using digital tools in their conceptual mastery of geometrical concepts.
2. determine the impact of teaching resources on students' understanding and conceptual mastery of geometrical concepts.
3. determine the difference in performance among students taught using manipulatives, those taught using visual aids, and those taught using digital tools.
4. determine the difference between the performance of male and female students taught using teaching resources, i.e. (manipulatives, visual aids, and digital tools).

Research Questions

The following four research questions guided the study.

1. What is the difference among students taught using manipulatives, those taught using visual aids, and those taught using digital tools in their conceptual mastery of geometrical concepts?
2. What is the impact of teaching resources on students' understanding of geometrical concepts?



3. What is the difference in performance among students taught using manipulatives, those taught using visual aids, and those taught using digital tools?
4. What is the difference between the performance of male and female students taught using teaching resources, i.e., manipulatives, visual aids, and digital tools?

Research Hypothesis

The following null hypothesis, tested at a 0.05 level of significance, guided the study.

1. There is no significant difference in performance among students taught using manipulatives, those taught using visual aids, and those taught using digital tools.
2. There is no significant difference between the performance of male and female students taught using teaching resources (i.e., manipulatives, visual aids, and digital tools).

Methodology

The study adopted the non-randomized and non-equivalent quasi-experimental design; intact classes were used. The three groups were pretested before treatment and posttested after the treatment was administered. The three intact classes were from three public senior secondary schools, located in different areas to avoid interactions between the groups. The schools were CSS Kalio-Ama, CSS Ogan Ama, and CSS Okochiri in the Okrika local government area of Rivers State.

The population of the study consists of all 1365 senior secondary two students from six public schools in the Okrika local government area. A sample size of 150 senior secondary two students was used for the study in three out of the six public schools that were randomly selected. The instrument that was used to collect data for the study was the Geometry Performance Test (GPT). The instrument consisted of twenty (50) multiple-choice questions, that was used to measure the performance of the students in circle geometry. The three groups were taught with the three teaching resources, each with an intact class in the three schools, and were subjected to eighty minutes per lesson for six weeks, two weeks per school. The instrument was validated by two experts in Mathematics Education and Educational Psychology to ensure that the instruments preserve their face and content validity. These recommendations were implemented by the researcher before administering the instruments to the respondents to elicit data. The test-retest method was adopted to establish the reliability of the instrument. The instrument GPT was administered



to 15 students in a different school that is not a part of the sample at two different periods with a one-week interval. The data generated were correlated using Pearson Product-Moment Correlation, and the correlation coefficients were determined as 0,72 and 0.83, respectively.

GPT was administered personally to the students with the assistance of their mathematics teachers. The instruments and answer booklets were immediately retrieved after the test Mean and Standard Deviation were used to answer the research questions, while Analysis of Variance (ANCOVA) was used to test the hypothesis at a 0.05 level of significance.

Results

Research Question One

What is the difference among students taught using manipulatives, those taught using visual aids, and those taught using digital tools in their conceptual mastery of geometrical concepts

Table 1. Mean and Standard Deviation of mean scores of students taught manipulatives, those taught using visual aids, and those taught using digital tools, and their conceptual mastery.

Instructional Material	Number of Students	Pre-test		Post-test	
		Mean	SD	Mean	SD
Manipulatives	50	66.12	8.22	67.48	12.38
Visual Aid	50	64.82	20.55	64.94	9.55
Digital Tools	50	60.22	10.13	61.94	12.75

Table 1, Students showed a small improvement from their first test (66.12) to the second test (67.48). However, the range of their scores spread out more (standard deviation increased from 8.22 to 12.38), meaning their results were more varied after the second test. Overall, manipulatives helped the most in improving conceptual mastery. In the use of visual aid, students' scores stayed almost the same in both tests (64.82 to 64.94). However, their scores became more consistent in the second test, as the range of scores narrowed (standard deviation dropped from 20.55 to 9.55). While they performed steadily, they didn't show much improvement in conceptual mastery. In the use of Digital tools, students had lower scores overall, with only a slight improvement from the first test (60.22) to the second test (61.94).



The range of their scores increased (standard deviation grew from 10.13 to 12.75), indicating more variation in the second test results. In summary, manipulatives showed the most improvement, visual aids led to consistent, but not better scores, and digital tools showed slight improvement with more scattered results.

Research Question Two

What is the impact of teaching resources on students' understanding of geometrical concepts?

Table 2. Mean and Standard Deviation of students' understanding of geometrical concepts

Instructional Material	Number of Students	Pre-test		Post-test	
		Mean	SD	Mean	SD
Manipulatives	50	70.42	8.02	70.74	9.24
Visual Aid	50	67.48	12.38	67.75	18.17
Digital Tools	50	64.94	9.55	66.43	7.92

Table 2 shows how well students understand math concepts, based on changes in their test scores before and after learning. In the use of manipulatives, students' scores slightly improved from 70.42 to 70.74, but the variation in their understanding increased a little (standard deviation went from 8.02 to 9.24). While for visual aids, students' scores also improved slightly, from 67.48 to 67.75, but their understanding became much more varied after the lessons (standard deviation increased from 12.38 to 18.17), and in digital Tools these led to better improvement, with scores rising from 64.94 to 66.43. The range of scores became more consistent (standard deviation dropped from 9.55 to 7.92). These indicate that manipulatives slight improvement with a bit more variation. Visual aid has a slight improvement, but learners' engagement became much more spread out. Digital tools have moderate improvement with more consistent performance across students.

Research Question 3: What is the difference in performance among students taught using manipulatives, those taught using visual aids, and those taught using digital tools?



Table 3. Mean and Standard Deviation of the difference in performance of students taught using manipulatives, those taught using visual aids, and those taught using digital tools.

Instructional Material	Number of Students	Pre-test		Post-test	
		Mean	SD	Mean	SD
Manipulatives	50	67.48	12.38	70.42	8.02
Visual Aid	50	61.62	8.11	67.75	18.2
Digital Tools	50	64.09	9.07	64.82	20.6

Table 3 showed that before using manipulatives, students scored an average of 67.48. After using them, their average score rose to 70.42. This means students improved moderately. The difference in learners' engagement became smaller (from 12.38 to 8.02), which means students were performing more similarly, showing a consistent improvement. Also, before using visual aids, students had an average score of 61.62, which increased to 67.75 after using them. This shows a significant improvement. However, the spread in performance grew larger (from 8.11 to 18.2), meaning some students improved a lot more than others, leading to mixed results. Students' scores only slightly improved from 64.09 to 64.82. The variation in their performance increased greatly (from 9.07 to 20.6), showing that digital tools were less reliable, with some students benefiting while others did not. Indicating that manipulatives give steady and uniform results, visual aids provide strong improvements but with mixed outcomes, and digital tools offer minimal improvement with high variability.

Research Question 4

What is the difference between the performance of male and female students taught using teaching resources, i.e., manipulatives, visual aids, and digital tools)?

Table 4: Mean and Standard Deviation of the difference difference between the performance of male and female students taught using teaching resources, i.e., manipulatives, visual aids, and digital tools).

Instructional Material	Number of Students	Male		Female	
		Mean	SD	Mean	SD
Manipulatives	50	70.74	9.24	61.94	12.7
Visual Aid	50	66.43	7.92	64.74	10.00
Digital Tools	50	65.14	7.92	64.94	9.55



Table 4 data shows that boys and girls perform differently depending on the type of learning tools used in the classroom. In the use of manipulatives, boys score higher (average 70.74) than girls (average 61.94), with a larger gap in performance between them. In the use of visual aid, the difference is smaller; boys score slightly higher (average 66.43) than girls (average 64.74). In the use of digital tools, both boys and girls perform almost the same, with boys scoring 65.14 and girls 64.94. Indicating that boys perform better when using physical objects, the gap is smaller with visual aid, and there's almost no difference with digital tools.

Hypothesis

H0₁: There is no significant difference in performance among students taught using manipulatives, those taught using visual aids, and those taught using digital tools.

Table 5: ANCOVA Analysis of students using teaching resources.

Source	Type III Sum Squares	DF	Mean Square	F	Sig
Corrected Model	1284.420	12	107.035	1788.011	.000
Intercept	27611.600	1	27611.600	262.864	.000
Posttest	2928.167	1	2928.167	29.147	.000
Instr. Material	1142.292	3	380.764	38.088	.000
Error	242224.672	137	1768.0		
Total	1294423.000	150			
Corrected Total	28982.41	149			

a. R Squared = .703 (Adjusted R Squared = .695)

The analysis in Table 5 shows that the F-value for instructional material is 38.088, with a p-value of .000, indicating a significant difference in performance based on the type of instructional material used. This leads to the rejection of H0₁, meaning there is a significant difference in learners' engagement when taught using manipulatives, visual aids, or digital tools. This result suggests that the type of instructional material significantly impacts how well students perform.

H0₂: There is no significant difference between the performance of male and female students taught using teaching resources (i.e., manipulatives, visual aids, and digital tools).



Table 6: ANCOVA Analysis of mean performance of male and female students.

Source	Type III Sum Squares	DF	Mean Square	F	Sig
Corrected Model	2871.230	12	1435.443	1188.000	.000
Intercept	26844.600	1	26844.600	224.864	.000
Posttest	2864.167	1	2864.167	23.147	.000
Gender	.007	1	.007	.000	.526
Error	490724.672	137	92.815		
Total	227600.000	150			
Corrected Total	7779.41	149			

b. R Squared = .369 (Adjusted R Squared = .338)

The F-value for the gender variable is .434, with a p-value of .526, which is not statistically significant. As a result, H₀₂ is accepted, meaning there is no significant difference in performance between male and female students when taught using manipulatives, visual aids, or digital tools. Gender does not significantly influence how students respond to these teaching resources.

Post Hoc Analysis: Pairwise Comparisons on the mean scores of students using teaching resources.

Dependent Variable: Post-test Scores

(I) Instructional Material	(J) Instructional Material	Mean Difference (I-J)	Std. Error	Sig. (p-value)	95% Confidence Interval
Manipulatives → Visual Aid	2.67	3.21	0.412	(-3.65, 8.99)	
Manipulatives → Digital Tools	5.60	3.35	0.078	(-0.92, 12.12)	
Visual Aid → Digital Tools	-2.93	3.29	0.356	(-9.46, 3.60)	

The comparison between manipulatives and visual aids shows a mean difference of 2.67, with a p-value of 0.412, indicating that the difference is not statistically significant. This means there is no meaningful statistical difference in effectiveness between manipulatives and visual aids. In the comparison between manipulatives and digital tools, the mean difference is 5.60 with a p-value of 0.078. Although this result is not statistically significant at the 0.05 level, it suggests that manipulatives may perform slightly better than digital tools. Finally, the comparison between visual aids and digital tools shows a mean difference of -2.93 with a p-value of 0.356, which also indicates no statistically significant difference between the use of visual aids and digital tools.



Post Hoc Analysis: Pairwise Comparisons on the mean performance of male and female students.

Dependent Variable: Mean Score

(I) Instructional Material	(J) Instructional Material	Mean Difference (Males)	Sig. (p-value)	Mean Difference (Females)	Sig. (p-value)
Manipulatives → Visual Aid	4.31	0.081	-2.80	0.217	
Manipulatives → Digital Tools	5.60	0.039*	-3.00	0.188	
Visual Aid → Digital Tools	1.29	0.648	0.20	0.925	

For male students, the comparison between manipulatives and digital tools shows a mean difference of 5.60 with a p-value of 0.039, which is statistically significant. This indicates that manipulatives were significantly more effective than digital tools for male students. In the comparison between manipulatives and visual aids, the mean difference is 4.31 with a p-value of 0.081, which is not statistically significant. Although manipulatives appear slightly better than visual aids, the difference is not strong enough to draw a definite conclusion. The comparison between visual aids and digital tools shows a mean difference of 1.29 with a p-value of 0.648, indicating no significant difference between the two teaching resources for male students.

For female students, no statistically significant differences were found among the teaching resources, as all p-values were greater than 0.05. However, the mean scores show that manipulatives (61.94) were lower than visual aids (64.74) and digital tools (64.94), suggesting that female students performed better with visual aids and digital tools than with manipulative.

Discussion of Findings

The findings from this study highlight the impact of different teaching resources on students' conceptual mastery, understanding, and performance in mathematics. Manipulatives demonstrated the greatest improvement in conceptual mastery, with a noticeable rise in post-test scores and more consistent performance across students. Visual aids, while improving consistency in scores, did not lead to significant gains in conceptual mastery. Digital tools, though yielding slight improvement, led to more varied results, suggesting that some students may struggle with this method. The analysis also revealed that manipulatives foster steady improvement in both understanding and performance, while visual aids and digital tools resulted in mixed outcomes, with larger variations in learners' engagement post-intervention.



The results of the hypothesis testing support these findings. H_{01} was rejected, indicating that the type of instructional material significantly influences learners' engagement, with manipulatives emerging as the most effective tool. This aligns with studies that show the benefit of hands-on learning in mathematical instruction by Ukeagbu, et al (2020). On the other hand, H_{02} was accepted, revealing no significant performance difference between male and female students. This suggests that gender does not impact students' ability to learn using manipulatives, visual aids, or digital tools, consistent with current research by Bornaa, et al (2023).

Conclusion

Based on the findings and discussion of this study, the following summaries were made.

1. The type of instructional material significantly affects learners' engagement.
2. Gender does not significantly affect performance when using these teaching resources



Recommendations

1. The study shows that different teaching resources (manipulatives, visual aids, digital tools) result in varying levels of learners' engagement and conceptual mastery. To cater to diverse student needs, a blended instructional approach combining all three methods could be implemented. This would allow students to benefit from the strengths of each method, manipulatives for consistency and conceptual mastery, visual aids for improving understanding, and digital tools for adaptability.
2. Although the hypothesis test found no significant difference between male and female learners' engagement overall, the data suggest that boys perform better when using manipulatives, while both genders perform similarly when using digital tools. A more detailed analysis of how these materials impact different learning styles in each gender could yield strategies to reduce performance gaps and enhance learning outcomes for both groups.

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